VITERBI SLICER FOR TURBO CODES

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application claims priority from provisional application number 60/168,809 entitled VITERBI SLICER FOR TURBO CODES filed on December 03, 1999, which is incorporated by reference herein as set forth in full.

BACKGROUND OF THE INVENTION

As coding technology improves signals can be decoded with lower signal to noise ratios. Decreasing signal levels that can be decoded require receivers that can acquire and track at lower signal levels. There is therefore a need in the art for receiver technology to enable the acquisition and tracking of signals at lower signal levels.

SUMMARY OF THE INVENTION

In one aspect of the present invention, a method of processing signals includes receiving first and second signals each being modulated on a carrier signal, the first signal preceding the second signal in time, multiplying each of the first and second signals with a reference signal having a reference frequency, adjusting the multiplied first signal based on the multiplied first and second signals, comparing the adjusted first signal to the multiplied first signal, and adjusting the reference frequency as a function of the comparison.

In another aspect of the present invention, a receiver includes an oscillator having a reference signal output with a tunable reference frequency, a multiplier to multiply a first signal with the reference signal, and to multiply a second signal, succeeding the first signal in time, with the reference signal, the first and second signals each being modulated on a carrier frequency, a decoder to adjust the multiplied first signal based on the multiplied first and second signals, and a detector to compare the adjusted first signal with the multiplied first signal, the detector being adapted to tune the reference frequency as a function of the comparison.

In yet another aspect of the present invention, a receiver includes an oscillator having a tuning input, a multiplier having a first input to receive a signal, and a second input coupled to the oscillator, the signal comprising a first signal and a second signal succeeding the first signal in time, the first and second signals each being modulated on a carrier frequency, a decoder having an input coupled to the multiplier, and an output, and a detector having a first input

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coupled to the decoder input, a second input coupled to the decoder output, and an output coupled to the tuning input of the oscillator.

In a further aspect of the present invention, a receiver includes oscillator means for generating a reference signal having a tunable reference frequency, multiplier means for multiplying a first signal with the reference signal, and multiplying a second signal, succeeding the first signal in time, with the reference signal, the first and second signals each being modulated on a carrier frequency, decoder means for adjusting the multiplied first signal based on the multiplied first and second signals, and detector means for comparing the adjusted first signal with the multiplied first signal, the detector means comprises tuning means for tuning the reference frequency as a function of the comparison.

In yet a further aspect of the present invention, a method of processing signals having a first and second symbol each representing a constellation point, the first symbol preceding the second symbol in time, includes quantizing the first symbol to its nearest constellation point as a function of the first and second signals, comparing the first symbol to the quantized first symbol, and adjusting a reference frequency as a function of the comparison.

In still a further aspect of the present invention, a receiver to receive a signal including first and second symbols each representing a constellation point, the first symbol preceding the second symbol in time, includes a decoder to quantize the first symbol as a function of the first and second symbols, a detector to compare the first symbol to the quantized first symbol, and an oscillator having a tunable output as a function of the comparison.

In another aspect of the present invention, a communications system includes a transmitter to transmit a signal including first and second symbols each representing a constellation point, the first symbol preceding the second symbol in time, and a receiver including a decoder to quantize the first symbol as a function of the first and second symbols, a detector to compare the first symbol to the quantized first symbol, and an oscillator having a tunable output as a function of the comparison.

It is understood that other embodiments of the present invention will become readily apparent to those skilled in the art from the following detailed description, wherein it is shown and described only embodiments of the invention by way of illustration of the best modes contemplated for carrying out the invention. As will be realized, the invention is capable of other and different embodiments and its several details are capable of modification in various other respects, all without departing from the spirit and scope of the present invention. Accordingly, the drawings and detailed description are to be regarded as illustrative in nature and not as restrictive.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings where:

Figure 1 is a graphical illustration of a prior art communications system.

Figure 2 is a graphical illustration of a communication system in which the coding section comprises a turbo encoder.

Figure 3 is a graphic illustration of a communication system according to an embodiment of the invention.

Figure 4 is a graphic illustration of a communication system according to an embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Figure 1 is a graphical illustration of a communications system. In Figure 1, data 101 is provided to an encoder 103. The encoder codes the data and then provides it to a transmitter 105. The transmitter modulates the coded data on a carrier frequency, amplifies the resultant signal and broadcasts it to a relay satellite 107. The relay satellite 107 then rebroadcasts the data transmission to a receiver 109. The received signal is then provided by the receiver 109 to a mixer 113. A voltage controlled oscillator 123 provides a mixer signal to the mixer with the result that the coded signal is translated to a baseband signal. The coded baseband signal comprises the data and the coding added by encoder 103. The transport interface of the signal from (and including) the transmitter 105 to (and including) the receiver 109 is referred to as a channel 111.

The coded data from the multiplier 113 is filtered (filter not shown) and provided to a slicer 115. The slicer 115 extracts symbols from the coded data stream and provides it to a decoder 119. The decoder 119 decodes the symbols and creates a data stream 121. A phase detector 117 compares the symbol found by the slicer 115 with the value input to the slicer. By comparing the signal input to the slicer to the actual symbol found by the slicer in the phase detector 117, the phase detector detects whether the slicing process is leading or lagging the actual symbol value detected within the data stream. The phase detector 117 can then adjust the voltage controlled oscillator 123 to adjust the mixer signal provided to the multiplier 113 to match the carrier signal.

Figure 2 is a graphical illustration of a communication system in which the encoder 103 is replaced by a turbo encoder 200. The turbo encoder 200 accepts data 201. The data is then

encoded in a first trellis encoder 203. The data is also interleaved by an interleaver 205 and provided to a second trellis encoder 207. The second trellis encoder 207 may be identical to the first trellis encoder 203, but it may also be different. The outputs of trellis encoders 203 and 207 are then punctured by switch 209. In other words, switch 209 selects between the output of trellis encoder 203 and trellis encoder 207. The punctured output of turbo encoder 200 is then provided to a channel 211.

The signal received from the channel is then coupled into a multiplier 213, and the received signal is mixed with a mixer signal (as provided by the VCO 223), which replicates the carrier signal. The slicer 215 slices the symbols from the data stream, and the phase detector 217 detects the difference between the sliced symbol found at the output of the slicer 215 and the value input to the slicer. The output of the phase detector then adjusts the VCO 223 in order to correct the carrier signal being mixed in multiplier 213. The output of the slicer is then coupled into turbo decoder 219 to decode the turbo encoded data.

Turbo encoder 200 is a parallel concatenated encoder. Parallel concatenated codes ("turbo codes") allow communications systems to operate near the Shannon capacity. However, when operating in this region, the signal to noise ratio may be very low. This low signal to noise ratio (E_S/N_O) can make synchronization with a received signal difficult. If the channel symbol error rate is greater than 1:10 (i.e., one out of ten transmitted signals is decoded incorrectly), a decision directed loop, such as illustrated in Figure 2 (comprising the slicer 215 and phase detector 217) can fail. In order to improve the accuracy, the slicer 215 may be replaced by a Viterbi decoder as illustrated in Figure 3. Viterbi decoders typically produce the most likely channel symbol based on past data, present data and (depending on trace-back depth) future data. A Viterbi decoder uses the past and future data as well as correlations within the data to produce a current symbol that is more likely to be correct than if only the present data is used (such as with a typical data slicer). In the embodiment illustrated in Figure 3, future data is not available, so the Viterbi decoder 301 will examine past and present data in order to produce a symbol, which is more likely to be accurate than one determined by a slicer mechanism such as illustrated in Figure 2. A Viterbi decoder is more likely to make an accurate decision as to what the symbol being decoded is based on a history of inputs than can a slicer, which makes a decision based on only the present input.

The turbo encoder 200, however, is a parallel concatenated encoder. Turbo encoder 200 comprises two trellis encoders separated by an interleaver 205. Any number of trellis encoders separated by interleavers may be used, but two are shown for sake of simplicity.

The interleaver 205 accepts the data 201 and interleaves or shuffles the data before providing it to the trellis encoder 207. As a result, the data provided by the lower leg of the turbo

encoder comprising the trellis encoder 207 is out of sequence and must be resequenced. For this reason, switch 303 is added to the Viterbi decoder 301 so that only the symbols from trellis encoder 203 or trellis encoder 207 are used by the phase detector 217 to adjust the controlled oscillator 223. The delay introduced by interleaver 205 makes it impractical for the Viterbi decoder 301 to use symbols from both sides of the turbo encoder 200 without a buffering and delay mechanism at the input of the Viterbi decoder. Switch 303 will select every other symbol. Either a symbol from trellis encoder 203 will be selected or a symbol from trellis encoder 207 will be selected by switch 303.

Figure 4 is a graphical illustration of a communication system according to an embodiment of the invention. In Figure 4, the turbo encoder 403 has been modified by placing an inverse interleaver in series with trellis encoder 207. The inverse interleaver 401 unscrambles the order of the data which had been scrambled by the interleaver 205, after it has been trellis encoded. By utilizing inverse interleaver 401, every symbol can be used by the Viterbi decoder 301 in order to synchronize the frequency of the VCO 223.

Although a preferred embodiment of the present invention has been described, it should not be construed to limit the scope of the appended claims. Those skilled in the art will understand that various modifications may be made to the described embodiment. Moreover, to those skilled in the various arts, the invention itself herein will suggest solutions to other tasks and adaptations for other applications. It is therefore desired that the present embodiments be considered in all respects as illustrative and not restrictive, reference being made to the appended claims rather than the foregoing description to indicate the scope of the invention.